Paper Submission for:

9th International Command and Control Research and Technology Symposium
Coalition Transformation: An Evolution of People, Processes and
Technology to Enhance Interoperability

Topics
C2 Assessment Tools & Metrics
C2 Human Factors Engineering
Decision Making and Cognitive Analysis

Title of Paper
Constructible Assessment for Situation Awareness in a Distributed C2 Environment

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			Form Approved OMB No. 0704-0188

Report Documentation Page

1. REPORT DATE **SEP 2004**	2. REPORT TYPE	3. DATES COVERED **00-00-2004 to 00-00-2004**

4. TITLE AND SUBTITLE **Constructible Assessment for Situation Awareness in a Distributed C2 Environment**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **DSO National Laboratories,Defence Medical and Environmental Research Institute,27 Medical Drive #11-00,Singapore 117510 Singapore, ,**	8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**

13. SUPPLEMENTARY NOTES **The original document contains color images.**

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES **36**	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**			

Constructible Assessment for Situation Awareness in a Distributed C2 Environment

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Abstract

A method for assessing situation awareness (SA) in field command and control exercises is described in this paper. This is an adaptation of the Situation Awareness Global Assessment Technique (Endsley, 1995a), taking into account specific constraints for use in a field exercise, such as minimising the level of intrusiveness. This constructible assessment for SA (CASA) requires that military subject matter experts observe exercise events, construct specific and relevant questions to probe the situational knowledge of the exercise participants and decide upon the suitable timings for administration of these questions. CASA was tested in a division-level army C2 exercise. An objective of the exercise was to investigate the issues of distributed command teams, using situation awareness as one of the measures. Having applied CASA in this exercise, the strengths and limitations of CASA were identified. To analyse the findings, several methods of computing situation awareness of teams were utilised. It was found that CASA yielded results consistent with expectations stemming from exercise roles and events. Further validation and refinement of CASA would improve its utility and efficacy as a tool to measure objective SA in a field exercise.

Introduction

Situation awareness (SA) can be defined in many ways. To some, SA essentially comprises "knowledge relevant to the task being performed… (and) is a critical component of decision making (Gawron, 2000)". It can also be construed as a process that consists of "keeping track of the prioritised significant events and conditions in one's environment (Oliver, 1990)".

This paper describes a method designed to objectively assess the SA of personnel within the constraints of a field exercise. Other attempts to measure SA in a field environment have utilized subjective scales and observer ratings (Matthews & Beal, 2002). However, the research team chose to adapt SAGAT, an objective measure of SA (Endsley, 1995a) because of its distinct advantages over subjective measures. This adapted form of SAGAT is named CASA (Constructible Assessment for Situation Awareness) for ease of reference in this paper.

CASA is based on Endsley's model of SA (1995b) which separates SA into three levels, namely: Level 1, perception of elements in the environment within a volume of

time and space; Level 2, the comprehension of their meaning and integration of multiple pieces of information; Level 3, the projection of the elements' future status and ability to forecast future situation dynamics. It consists of a set of questions that objectively probe situational knowledge of the subjects at selected points in time. The questions are constructed from a list of pre-defined question templates, with the option to create new questions where necessary. Various measures of SA can be quantified based on subjects' responses to the questions.

An attempt to validate CASA in an army command and control (C2) exercise by the research team is detailed in this paper. A previous paper describing a similar undertaking (French & Hutchinson, 2002) arising from similar motivations was found during the writing of this paper, after CASA had been developed and tested. However, differences exist in terms of methodological details and scope of analysis; these differences will be highlighted where relevant in the paper.

Background Of Exercise

The exercise was a division-level army C2 exercise investigating the effects of a distributed C2 setup. Traditionally, command teams are co-located in a physical command post from where the battle is controlled. An obvious advantage of such an arrangement is the ability to leverage upon physical proximity to facilitate information exchange and increase speed and quality of communication. This in turn enables members of the team to efficiently and effectively achieve an understanding of commander's intent and arrive at a common operational picture. Today, with advanced concepts such as network-centric warfare, command posts are moving towards distributed models that feature the added benefits of mobility, flexibility and agility. However, problems such as miscommunication and errors due to electronic messaging, as well as a loss of trust when individuals are not in direct contact or view of each other, may arise in distributed environments. Also, it remains to be tested whether the communication advantages of physical co-location are retained in a distributed environment.

In the exercise, three command teams were placed at different physical locations, the independent variable being the physical proximity to Superior HQ which had overall responsibility for the entire area of operations. The area of operations was partitioned into two and each placed under the command of Team A and B: Team A and HQ were co-located whereas Team B was located in a separate building about 100m away. The three teams used the same command and control information systems linked via network and there was no difference in their access to communication tools such as the telephone. No restriction was placed on the movements of the participants.

CASA was used in the exercise as part of a larger scale cognitive assessment to assess the impact of distributed versus co-located command teams. In addition to CASA, the assessment comprised subjective workload and subjective SA measures and video/audio records of communication activity. This paper reports the design of CASA, its method of administration in the exercise and findings; the other measures will be discussed in a follow-up paper.

Constructible Assessment For Situation Awareness (CASA)

CASA is adapted from the SAGAT methodology, a well-validated method of measuring SA objectively (Endsley & Garland, 2000) that has been applied extensively to military settings. However, the research team felt that certain aspects of the technique could be modified for better applicability to an army field exercise with its inherent constraints.

Firstly, frequent administration of SAGAT questions at random times is not always possible because of the level of intrusiveness imposed. The exercising unit may not be prepared to have too many interruptions to the progression of its exercise and the blanking out of display screens for a SAGAT administration may be deemed too jarring. Furthermore, in a typical field exercise, participants would be walking around the exercise area and may not be present for a SAGAT administration if administration times were randomly chosen and displayed on a terminal.

Secondly, the random selection of SA questions from a pool of prepared questions could result in "wasted" probes not relevant to the unfolding exercise events at the time of administration. While random selection has its advantages of statistical validity and objectivity, but if exercise conditions do not allow for a large number of SAGAT administrations, every administration should be designed to count.

In order to circumvent these constraints, CASA was developed by retaining the structure of SAGAT with several modifications to both methodology and subsequent analysis. As in SAGAT, CASA involves the creation of a list of SA questions prior to the exercise, from which a subset of relevant SA questions are selected for each administration. However, there are several key differences from SAGAT.

CASA Features

CASA places emphasis on tailoring each administration to ensure that questions relevant to the exercise context at that time and its near future will be asked, rather than from a random selection. Military Subject Matter Experts (SMEs) construct specific CASA questions by first considering how events had unfolded and would unfold in the exercise, then selecting the desired questions from the list of question templates. The selected question templates would then be "fleshed out" with the appropriate unit names, attributes or relationships of interest. CASA is not a closed tool; the list of question templates can be supplemented with new questions created during the exercise in response to novel and unanticipated situations. These new questions can then be generalised and added to the list of question templates, progressively making CASA more comprehensive in coverage.

CASA allows the flexibility in selection of administration timings to be done by SMEs instead of being randomised. However, caution needs to be taken to ensure that the administration times do not follow an overt pattern (e.g. during rest periods) so as to prevent the subjects from pre-empting and preparing for an administration.

The selection flexibility of the question templates and administration timings endows CASA with a diagnostic capability, as French and Hutchinson (2002) have also noted. For example, if the military SMEs observe or suspect that there may be an

information bottleneck at a certain point in time, a selection of CASA questions can be specifically chosen to investigate if this is true. Such a capability makes CASA a more powerful tool, able to probe into situations in addition to being an objective measure of SA.

Another way in which CASA is administered differently from SAGAT is the posing of common questions across different roles, unlike SAGAT where subjects in different roles are given unique sets of questions. While it may be argued that this may result in irrelevant questions for some subjects, the research team believes that an awareness of information outside one's focused sphere of operation allows for better appreciation of the overall situation, e.g. the constraints and problems faced by team-mates. Also, since all subjects answered a common set of questions at every administration, it is possible to compare across subjects at each administration as well as at an aggregate level.

CASA Questions

Table 1 shows examples of CASA question templates. There are several question types that are used in CASA: multiple-choice questions, open-ended and map-based. A question template is "fleshed out" by replacing the placeholders in square brackets with concrete terms. The correct answers to each question should be noted down by referring to ground truth at the appropriate times.

Situation Awareness Level	Sample Question Template	Answer Type
Level 1	1. Mark the current location of [hostile/friendly unit] on the map. 2. What is the current force size of [hostile/friendly unit]?	1. Marking on map. 2. Open-ended but constrained by context.
Level 2	1. What is the most critical additional asset that [friendly unit] requires to carry out its mission? 2. Which one of these hostile units currently poses the highest threat priority to this [friendly unit]?	1. Open-ended but constrained by context 2. Multiple Choice
Level 3	1. When is the earliest projected time for the securing of [location]? 2. Is [hostile unit] likely to be in contact with friendly unit(s) by [time]?	1. Multiple Choice 2. Yes / No

Table 1 – Examples of CASA question templates

Measures Of Situation Awareness

The following measures of SA can be obtained from the results of CASA.

Individual SA is the percentage of correct responses an individual makes to the SA questions posed. **Group SA** is the level of situation awareness in a team of individuals as a whole, which is the percentage of the total number of correct responses by all members of the team. **Shared SA** is an indication of how two or more individuals share an awareness of the situation among themselves, computed by the percentage of similarly answered questions by all individuals. Shared SA can be

based on similarly right and/or wrong responses depending on the desired analysis. **Complementary SA** is another way of measuring the SA of a team, where not all members are expected to have common knowledge about the situation. It is assumed that complementary roles within the team cover each other and information is volunteered and shared freely. For Complementary SA, as long as one member of the team responds correctly, the question is considered correctly answered for the entire team. Table 2 illustrates how levels of individual, group, shared and complementary situation awareness are computed.

Question	X's answer	Y's answer	Z's answer
1	(a) ✓	(a) ✓	(c) ✗
2	(b) ✗	(b) ✗	(c) ✗
3	(a) ✓	(a) ✓	(a) ✓
4	(c) ✗	(d) ✓	(d) ✓
5	(d) ✓	(d) ✓	(b) ✗

Individual X SA = 3 ÷ 5 = 60%
Group XY SA = 7 ÷ 10 = 70%
Group XYZ SA = 9 ÷ 15 = 60%
Shared* XY SA = 4 ÷ 5 = 80%
Shared* YZ SA = 2 ÷ 5 = 40%
Shared* XYZ SA = 1 ÷ 5 = 20%
Complementary SA of XYZ = 4 ÷ 5 = 80%

* In this illustration, wrong answers contribute to Shared SA if respondents answered similarly

Table 2 – Computation of Levels of Situation Awareness

CASA In A Distributed Environment

CASA was first fielded as a measure of situation awareness in the army exercise described in this paper. As the exercise was not conducted primarily for the purpose of our research, the administration was subject to numerous constraints. The exercise was conducted in 2003 for duration of 36 hours over 3 days.

Pre-Exercise Preparation

A month before the exercise, a list of assessment question templates was created by the research team via interviews with two military SMEs. Regretfully, a cognitive task analysis was not performed because of a lack of time. The purpose of the interviews was to identify information requirements of commanders in accomplishing their tasks. As per Endsley's three levels of situation awareness, the information requirements were then translated into templates for constructing questions pertaining to *Perception* (Level 1 SA*)*, *Comprehension* (Level 2 SA) and *Projection* (Level 3 SA).

There were 43 questions in the template, with additional ones later created by military SMEs during the exercise in response to unanticipated situations. This was a sufficiently large question base to avoid repetition so as to prevent subjects from focusing on specific aspects of the situation during the exercise.

9 subjects were identified for the CASA administration based on their roles: Head Operations, Head Intelligence and Commander of Teams A, B and Superior HQ. Another reason the sample was kept small was the effort required to identify the SA requirements for each role given the short preparation time afforded.

CASA Administration

A total of 5 CASA administrations took place in the exercise. With the research team were two military SMEs observing the exercise events. They would assess if the developing situation was sufficiently eventful to be suitable for a CASA administration. If so, a CASA questionnaire would be constructed by the SMEs together with the research team, by identifying when in the future to administer and constructing SA questions accordingly. This generally took approximately 1-2 hours from the time it was decided to conduct an administration to the actual administration. There were occasions when a planned administration was aborted due to a sudden or unanticipated change in scenario by Exercise Control. The medium of administration was printed hardcopies of the questionnaire with an attached exercise map for answering questions regarding locations, as well as a cover instruction sheet. The paper medium was chosen for the exercise since displays were not to be blanked out for an administration. There was also a lack of time to develop other electronic means of administration.

The CASA questionnaires were handed out to the 9 respondents within 5 minutes of the administration time that was decided upon. At the same time, the ground truth was noted down for grading purposes. Respondents were given 5 minutes to complete the questionnaires to discourage over-analyzing the questions and minimise the effects of memory decay. Unlike the protocol employed by French and Hutchinson (2002), the exercise was not frozen during these administrations. This avoided imposing too large a disruption but limited the sample size that could be surveyed simultaneously. Upon collection of the questionnaires, grading was done against the ground truth noted down earlier.

The diagnostic capability of CASA proved useful during the exercise when it was known that the status of an exercise task force may be ambiguous at a certain point in time. The SMEs wanted to find out which of the teams had accurate knowledge regarding the task force. By specifying appropriate questions, it was discovered that Team A and HQ were correctly informed whereas Team B (the distributed team) was still operating under wrong assumptions about the task force.

An analysis of the questions administered during the exercise (a total of 47 questions across the 5 administrations) showed that approximately 7 question types were particularly favored by the SMEs and used repeatedly with slight variation. Reasons for this could be unfamiliarity on the part of the SMEs with the CASA methodology, and hence reluctance to go through all question types in the template. It may also be due to the small number of administrations or the exercise scenario for the other questions to be relevant. Only a small proportion of the questions (less than 10%) was novel i.e. created outside the pre-defined types in the template.

Results

Responses were analysed in terms of individual, group, shared and complementary SA as described in Table 2.

Individual and Group SA Levels
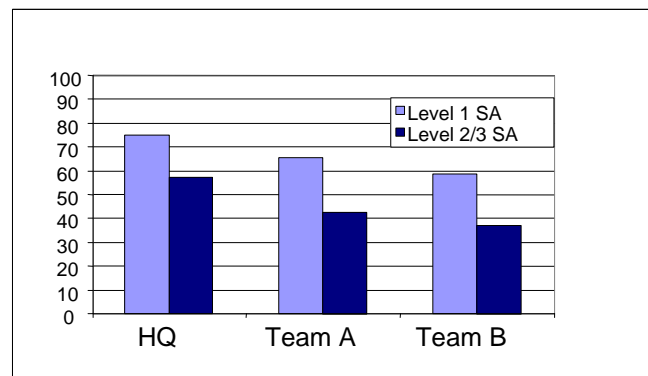
Figure 1 – Group SA levels by Team for all 5 administrations

Figure 1 presents the Group SA Levels of Superior HQ, Team A and Team B over all 5 administrations. Group SA in HQ is higher than that of Team A, which in turn is higher than Team B. It is logical that the SA of HQ would be higher than either team because HQ oversees the entire area of operation. Furthermore, the literature suggests that SA is correlated with the level of experience (Strater, Endsley, Pleban & Matthews, 2001); the HQ was staffed by regular officers who were more experienced than the military students staffing Teams A and B.
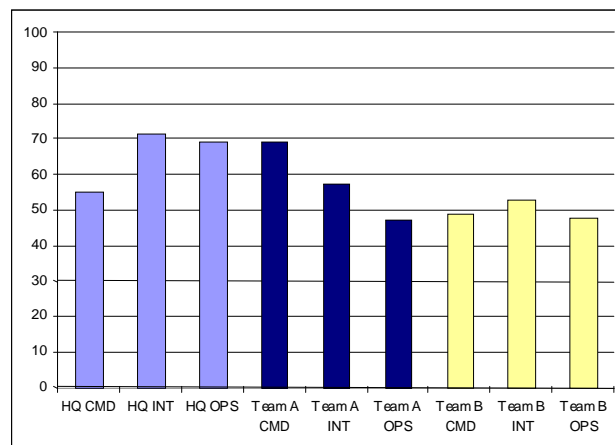

Figure 2 – Individual SA levels by Role for all 5 administrations

The graph in Figure 2 shows each individual's SA scores (combining the 3 SA levels) to enable comparisons to be made within each team, as well as to check for extremes of individual SA that could have skewed the Group SA results in Figure 1. It was not always the case that the commander of a team would have higher SA than his intelligence and operations officers. It can also be seen that the intelligence officers are marginally better than the operations officers, which is consistent with their roles.
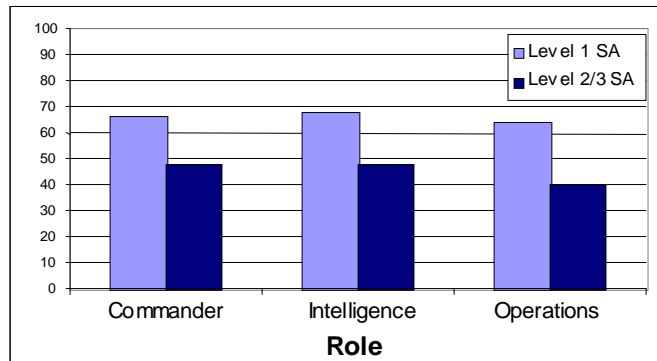
Figure 3 – Group SA by Role for all 5 administrations

As with SAGAT, CASA also allows a further breakdown of SA into three levels. Both Figures 1 and 3 shows that average Level 1 SA is higher than average Level 2/3 SA. It has been suggested that commanders should have better level 2/3 SA compared to level 1 as they are more focused on the "big picture". However, this was not the case in our study (see Figure 3). This may suggest that the subjects were more focused on perceptual elements of the scenario rather than integrating elements together and projecting into the future. The command and control information system was also designed primarily to convey factual information such as unit strengths, locations and terrain as opposed to unit relationships and status forecasts.
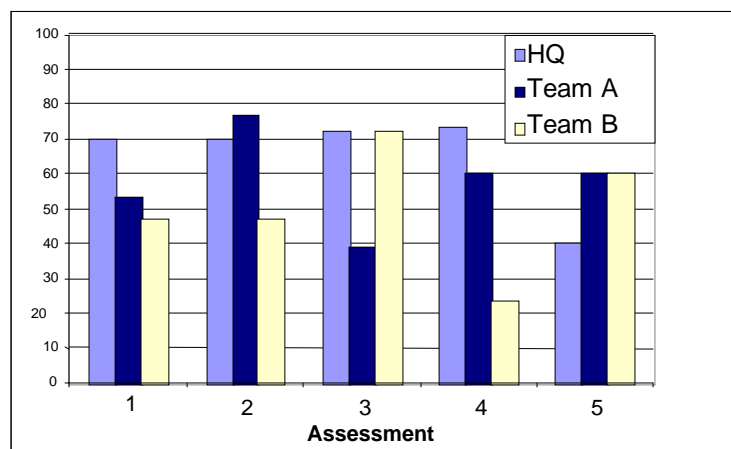

Figure 4 – Group SA by team and by administration

Figure 4 splits up the group SA scores into the 5 administrations but combines the 3 levels of SA. This gives an indication of how SA for each team varies across the 5 administrations. The reason for showing this graph is to highlight the third administration. Team A performed relatively poorly in this assessment compared to the other two teams. Due to certain exercise events, Team A completed their CASA questionnaire approximately one hour later than the other two teams. Because the exercise was not frozen for CASA administrations, events had changed and their answers no longer corresponded to the ground truth recorded earlier. This shows that the manner in which CASA was administered in the exercise was prone to lapses in timing.

Complementary and Shared SA Levels

Apart from Individual and Group SA levels, it is useful to assess how well members of a team share a common situation picture. On the other hand, it can also be argued that good team performance may not necessarily call for all team members to possess the same situation picture; rather, the combined awareness of the team is what matters. That is to say, as long as one member is aware of a certain piece of information, the team can pool their knowledge to arrive at a similarly high level of understanding and operation.

For this purpose, measures of shared and complementary SA within teams and between individuals from each team were calculated. In fact, the existence of pre-defined roles in a team (Commanders, Intelligence officers, etc.) may support the construct of complementary SA as being more useful than shared SA with the provision that knowledge sharing takes place when necessary according to military procedures.
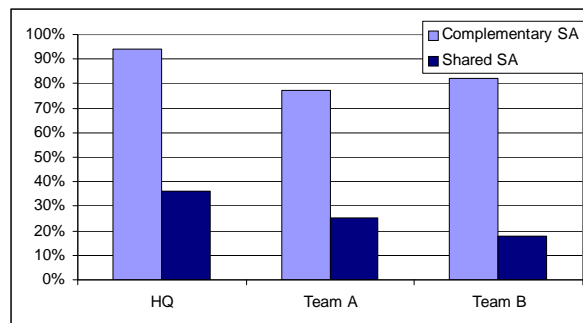
Figure 5 – Complementary and Shared SA by Team

Figure 5 shows Complementary SA versus Shared SA (computed as illustrated in Table 2) within each 3-person team, averaged across 5 administrations. It is evident that the two constructs do not vary in the same way between the teams. This could be a result of different team dynamics in each team. The results indicate that Team B's shared SA is half that of Superior HQ, but its level of complementary SA is nearly comparable. This may suggest a lack of communication between the team members regarding information they acquired (low Shared SA), however as a team, the different roles collectively "covered most bases" (high Complementary SA). Further diagnostic measures such as tracing communication activity within and between teams would be required to determine if this was so. Further comparisons against performance measures of the teams can elucidate which of the measures of team SA - group, shared or complementary, are most indicative of a successful working arrangement.

As part of the effort to compare distributed versus co-located teams, a graph was generated (Figure 6) to look at shared SA between counterparts in each team and Superior HQ. There did not appear to be a marked difference between the Shared SA for any of the roles.
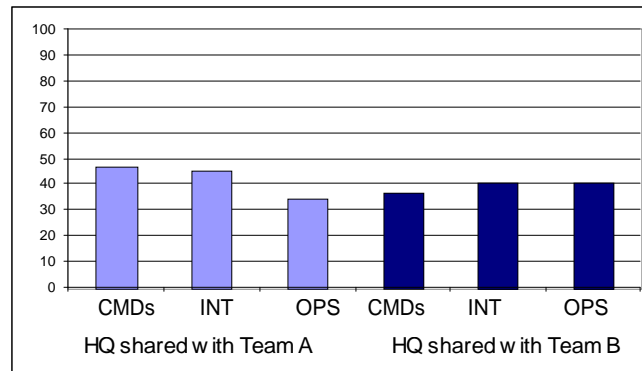
Figure 6 – Shared SA between counterparts in Teams and HQ

Discussion

The experience of having applied CASA in an actual exercise provided the research team with valuable insights that enabled refinements to be made to several aspects of the methodology.

The research team did not anticipate that CASA would be as manpower intensive as it was found to be in the exercise. The use of a paper medium required a team of people to generate questionnaires on word processors, print multiple copies, and disseminate them to the subjects within a very short time. It was felt that disseminating the questionnaires was the most difficult part of CASA as the subjects had to be located within the exercise compound in a matter of minutes. For future field assessments, CASA can be modified to become more easily self-administered, e.g. by issuing each subject with a wireless-enabled PDA on which SA questions would be displayed at the appropriate times, and the subject alerted to respond to the administration. An alternative to PDAs would be to get subjects to go to a room upon being alerted by a P.A. system or personal beepers to perform CASA at computer terminals. However, this assumes a high level of cooperation and adherence to the protocol on the part of the subjects and the exercising unit.

The military SMEs were also required to constantly monitor exercise events to select suitable administration timings and craft appropriate SA questions. This required them to be continuously alert and "on-the-job" at all times. As this was the first time that CASA was attempted, there were instances of uncertainty about whether an administration would be suitable or if the exercising unit would allow an intrusion at that time, as well as regarding the selection of questions and phrasing of new questions.

Concern was raised that the non-random nature of CASA may render it susceptible to bias, since the selection of questions and administration times are entirely dependent upon the SMEs' discretion. The questions selected for each administration should attempt to cover a wide range of SA requirements instead of solely querying about the most salient or prominent situation at that instance, to avoid drawing subjects' attentions to certain features of the situation following the administration. It is also recommended that at least two SMEs be employed when generating questions and

selecting administration timings so that the effect of individual biases is reduced. Administration times should not follow a predictable pattern, e.g. tied to particular exercise events such as rest periods, so that subjects cannot anticipate and prepare for an administration beforehand.

With regard to the analysis of CASA results, although no statistical tests were used in this case, CASA can in fact be subjected to statistical analysis if certain conditions were met. Specifically, increasing the sample size and number of administrations would allow for statistical testing, although the amount of effort required would increase accordingly. Experience from this exercise indicates that CASA is not suitable for administration at too short intervals due to the amount of time required to generate each questionnaire. It remains to be seen for future CASA assessments how quickly a questionnaire can be created to suit rapidly changing scenarios.

Conclusion & Future Work

While CASA has shown itself to be a reliable and effective method that can be applied to field exercises, it is acknowledged that data collection exercises of this nature are constrained by many factors, and some degree of trade-off is inevitable. To obtain strong statistical power and robustness of data analysis would necessarily entail a correspondingly high level of intrusiveness and effort on the part of the exercise participants. This fine balance between minimizing intrusiveness and maximizing data accuracy will have to be sought in future installations of CASA as well as any other cognitive assessments performed in conjunction with it.

To better validate CASA as a measure of SA, other measures such as SART (Taylor, 1990) for subjective assessment of SA can be employed at the same time as CASA to facilitate comparison between measures. As mentioned earlier, this was done to some extent in this exercise and the findings will be reported in a follow-up paper. The next logical step following this attempt at applying CASA in an exercise is to determine how various measures of effectiveness (MOE) correlate with the construct of SA as measured by CASA. For example, it would be valuable to assess if measures of SA are related to the amount of time taken to draw up a course of action. Other performance measures that can be investigated are kill ratios and quality of decisions as rated by military SMEs. This will aid in understanding the significance of cognitive measures such as situation awareness and how they translate into and impact performance in the military context.

Acknowledgement

The authors will like to thank both Head C4I Lab, SAF Centre for Military Experimentation, and Commanding Officer 3rd Signal Battalion, SAF, for supporting this research and in developing the CASA question templates. The authors will also like to extend appreciation to Members of C4I Lab, as well as the Officers of 3rd Signal Battalion, for their critical support in this work.

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Constructible Assessment for Situation Awareness

in a Distributed C2 Environment

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Outline

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  - Objectives of study
- **Constraints of experiments in field exercises**
- **Constructible Assessment for SA (CASA)**
  - Key features
  - Sample questions
  - Administration details
- **Results and Discussion**
- **Future Work**

Introduction

Background

- In 2003, an exercise was conducted by the Singapore Armed Forces to experiment with distributed but collaborative command and control processes

- Division-Level exercise with human participants in Brigade and Division-level command post; computer generated forces for fighting units

- One of the experimental conditions: Two command teams differed in physical proximity to HQ but otherwise have identical communication links and information systems

- Cognitive performance was among the variables being investigated

HQ

Team B

Team A
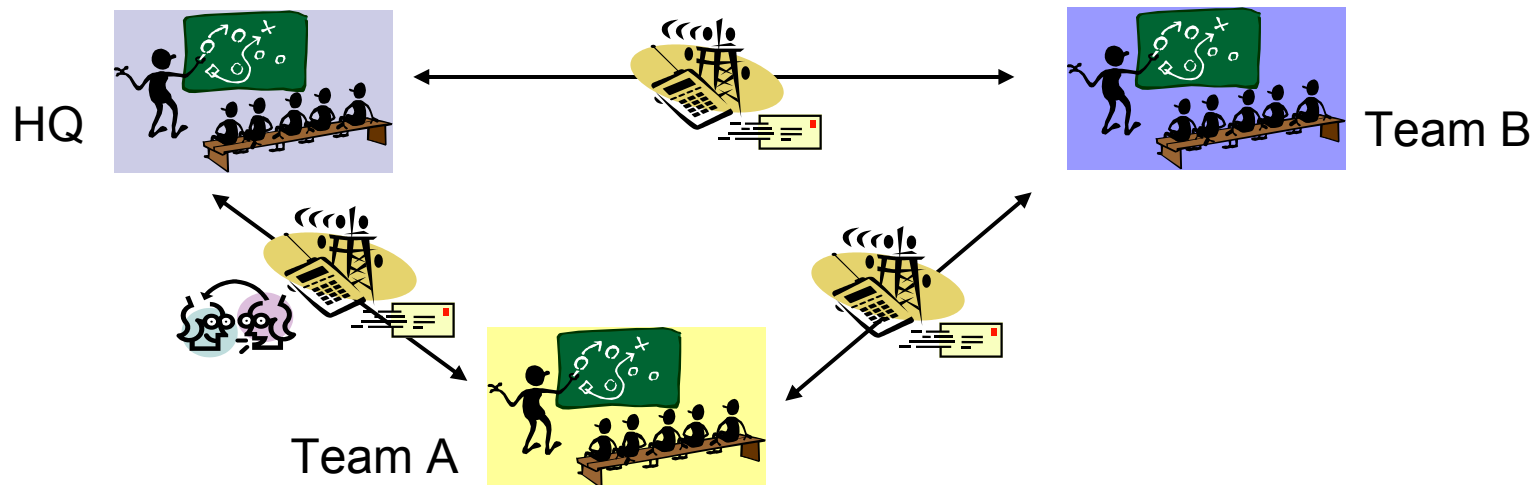
Introduction

Objectives of study

- To assess cognitive performance of command teams in the exercise
    - To attempt and evaluate various methodologies for cognitive assessment in the field
- To collect data on baseline cognitive performance of command teams

Cognitive performance assessment methods used

- Situation Awareness (SA)
    - Constructible Assessment For Situation Awareness (CASA)
    - Situation Awareness Rating Technique (SART)
- Workload
    - NASA-TLX
- Communication activity
   - Video/Audio recordings
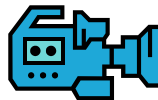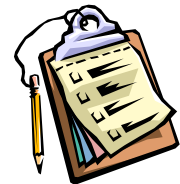
Constraints of experiments in field exercises

- Intrusiveness of data collection to be minimized
- Exercise events take precedence over data collection
- Low degree of experimental control - possibility of unexpected event injects from Director of Exercise
- Logistics challenge
  - Large number of participants (56)
  - Long duration (24hrs)
  - Physical mobility of participants

Categories of SA Measurement
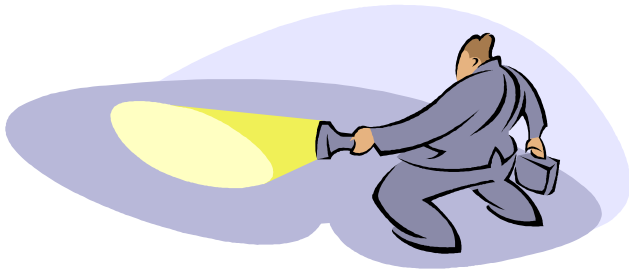
Direct experimental techniques

- Retrospective measures (e.g. recollection)
- Concurrent measures (e.g. verbal protocols)
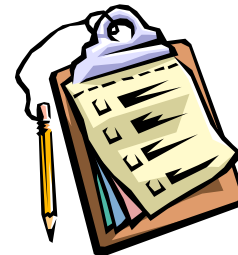- Psycho-physiological measures
- Direct questioning / freeze technique

Performance measures

- Global performance measures
- Subtask performance
- Performance in response to introduced anomalies or events

Subjective measures

- Direct self rating
- Comparative self rating
- Observer rating
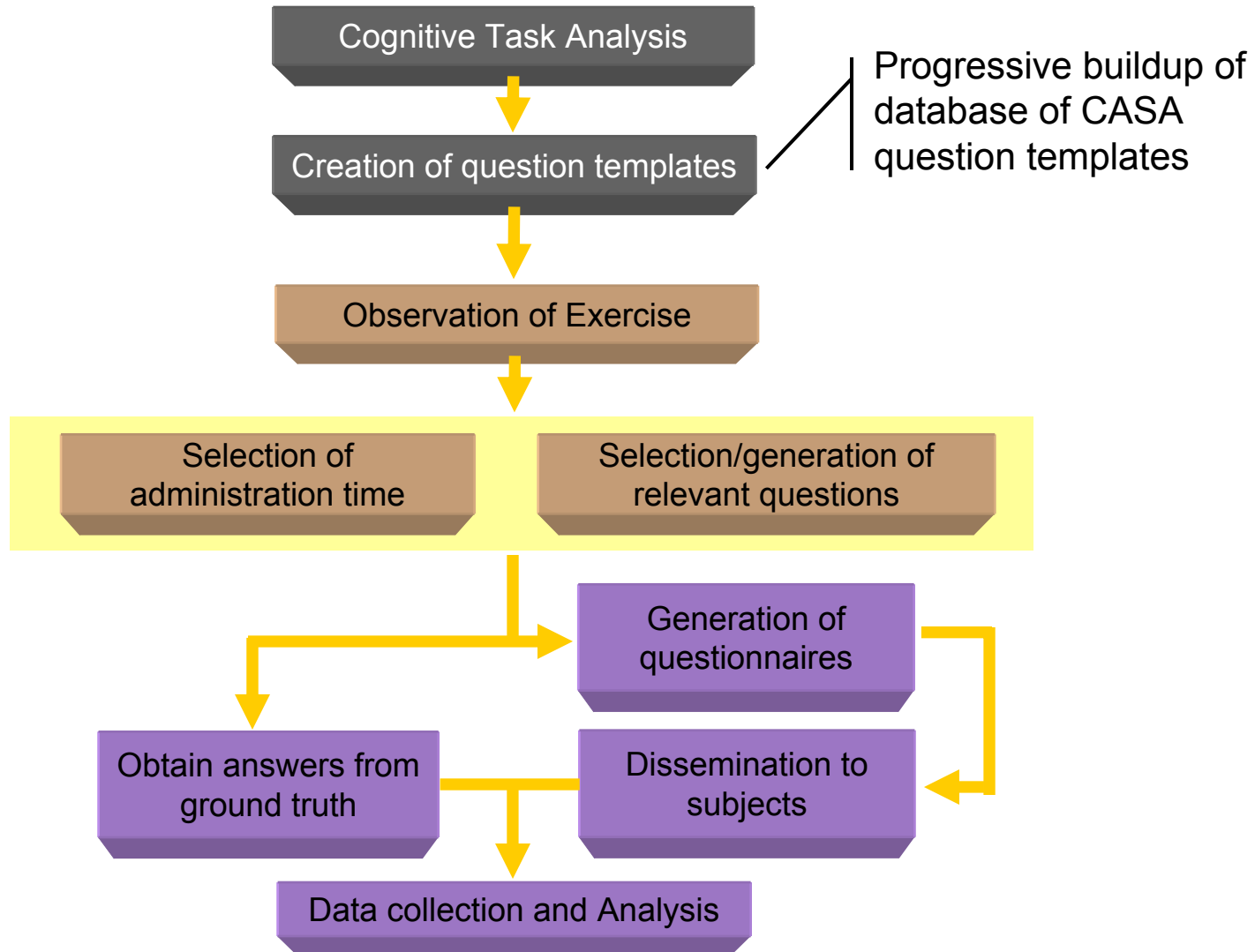
Endsley's SAGAT

- Direct (explicit) measure of SA that is well-validated and widely applied

- Based on three levels of SA (Endsley, 1991)
  - Level 1 : Perception of elements in the environment
  - Level 2 : Comprehension of the situation
  - Level 3 : Projection of future status

- Randomised administration
  - exercise or simulation will be frozen
  - randomly-selected pre-determined questions based on SA requirements
  - probes into knowledge of environment and events
  - SA is captured in real-time rather than post-hoc to reduce memory errors

Constraints of experiments in field exercises

- **Intrusiveness of data collection to be minimized**
  - Exercise freezes were not tolerated, administration times to be short (5 minutes)
  - Irrelevant questions from randomisation are a concern due to limited number of administrations over duration of exercise
- **Exercise events take precedence over data collection**
- **Low degree of experimental control - possibility of unexpected event injects from Director of Exercise**
- **Logistics challenge**
  - Large number of participants (56)
  - Nine key participants identified for objective SA assessment
  - Long duration (24hrs)
  - Physical mobility of participants
  - Paper-based administration

Workflow of CASA

Cognitive Task Analysis

Creation of question templates

Progressive buildup of database of CASA question templates

Observation of Exercise

Selection of administration time

Selection/generation of relevant questions

Generation of questionnaires

Obtain answers from ground truth

Dissemination to subjects

Data collection and Analysis

Examples of CASA questions

Question Formats

Level 1 SA

1. Mark the location of [red/blue] unit on map.
2. What is the current size force of [red/blue] unit? (e.g. "Coy+")

Level 2 SA

1. What is the most critical additional asset that [blue] unit requires to carry out its mission?
2. Which hostile unit currently poses highest threat priority to this [blue] unit?

Level 3 SA

1. When is the earliest projected time for the securing of [location]?
2. Is [red] unit likely to be in contact with [blue] unit by [time] ?

Answer Formats

- Only 1 correct answer per question
- Multiple choice questions
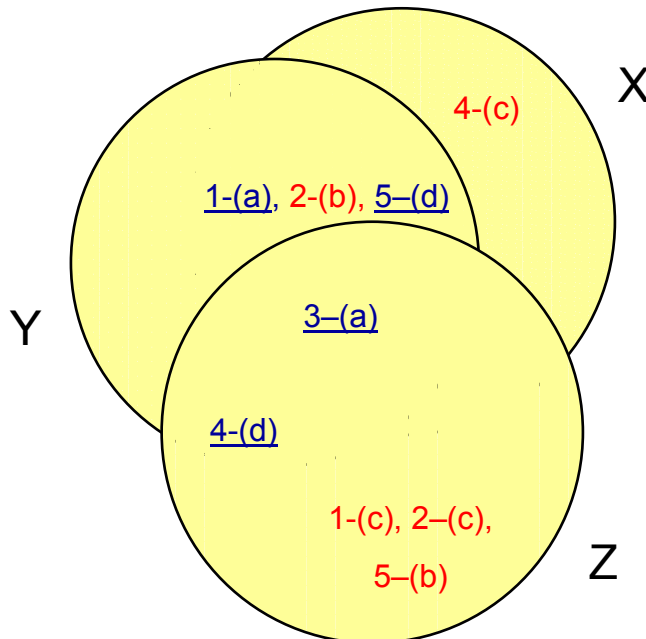- Map-based
- Open-ended (constrained by context)
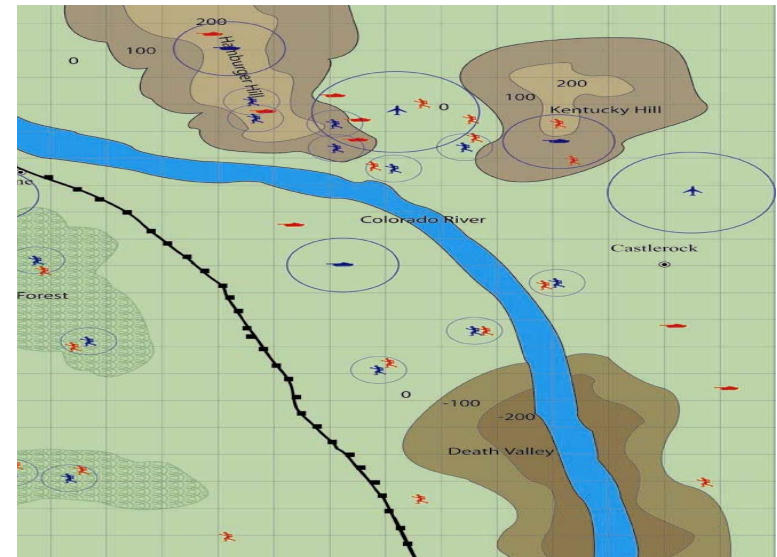
CASA Analysis

Question	X's answer	Y's answer	Z's answer
1	(a) ✓	(a) ✓	(c) ✗
2	(b) ✗	(b) ✗	(c) ✗
3	(a) ✓	(a) ✓	(a) ✓
4	(c) ✗	(d) ✓	(d) ✓
5	(d) ✓	(d) ✓	(b) ✗

Individual X SA = 3 ÷ 5 = 60%
Group XY SA = 7 ÷ 10 = 70%
Group XYZ SA = 9 ÷ 15 = 60%
Shared* XY SA = 4 ÷ 5 = 80%
Shared* YZ SA = 2 ÷ 5 = 40%
Shared* XYZ SA = 1 ÷ 5 = 20%
Complementary SA of XYZ = 4 ÷ 5 = 80%

* In this illustration, wrong answers contribute to Shared SA if respondents answered similarly

X

4-(c)

1-(a), 2-(b), 5–(d)

3–(a)

Y

4-(d)

1-(c), 2–(c),
5–(b)

Z

Shared SA = Intersection

Complementary SA = Union

Legend

1-(a) represents Question 1 being answered correctly with option (a)

2-(b) represents Question 2 being answered incorrectly with option (b)

Applying CASA

Pre-exercise preparation

- Nine subjects identified
  - (Commander, Operations, Intelligence) x 3 teams
- Generation of CASA question templates
  - Interviews with 2 military Subject Matter Experts (SMEs)
  - Identified information requirements of Commanders, Operations and Intelligence officers to complete their tasks
  - Categorised requirements into three levels of SA
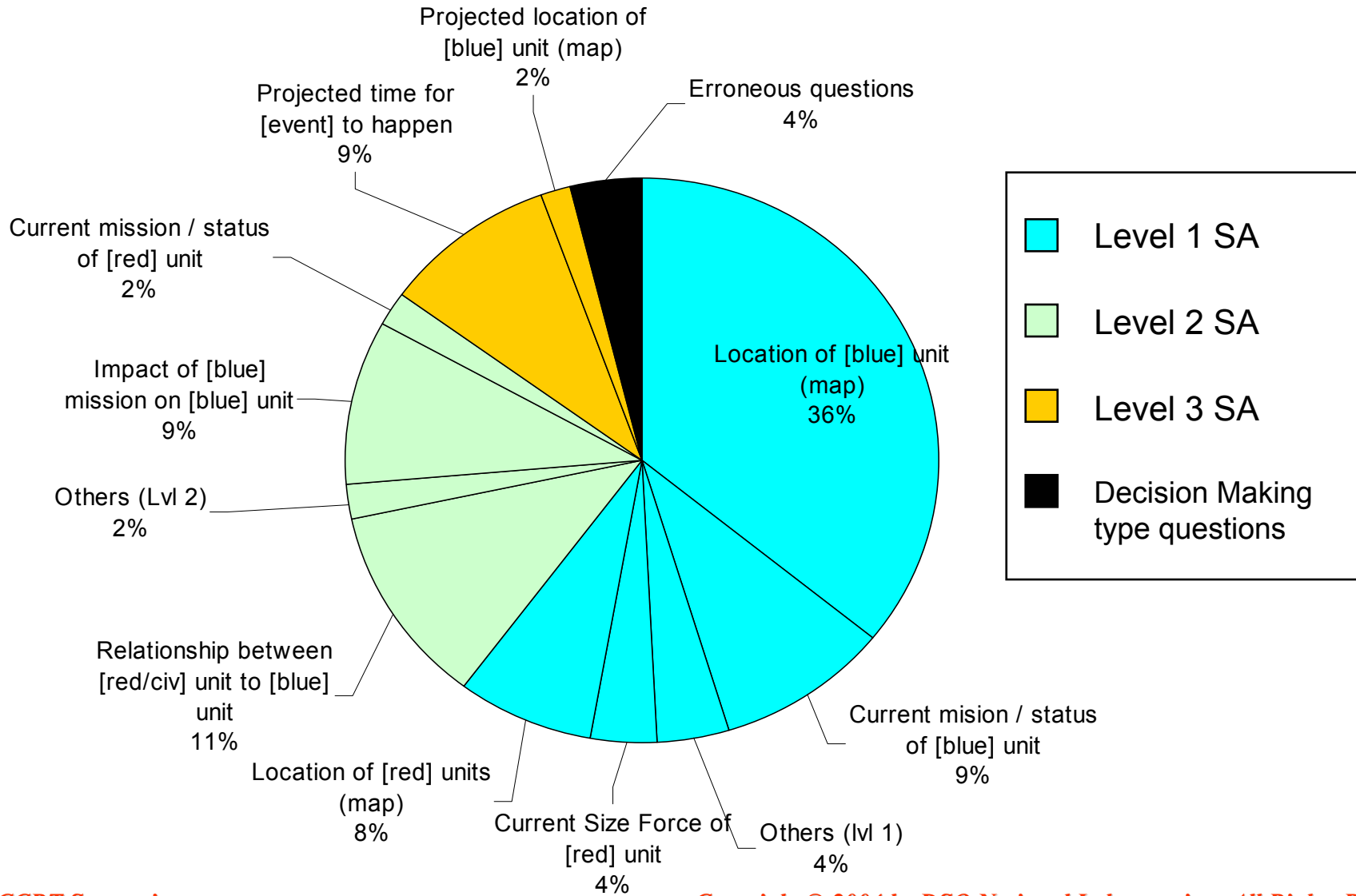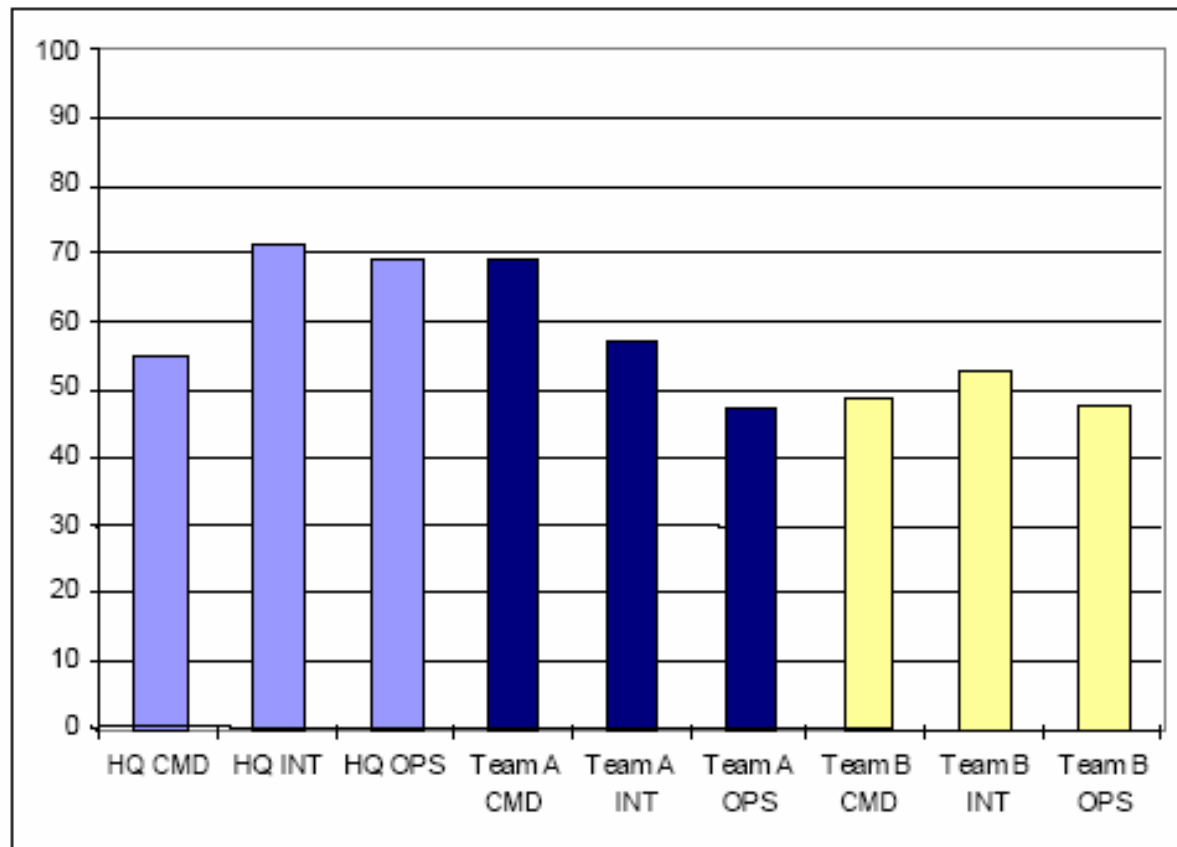 - Translated information requirements into questions

Applying CASA

<u>During the exercise</u>

- Questionnaires were constructed 1-2 hours from the time it was decided to have an administration; jointly by DSO researchers and SMEs

- Disseminated to subjects within 5 minutes of time of administration

- Subjects completed questionnaires (10 or less questions) within 5 minutes

- Answers to queries (ground truth) were recorded at the appropriate times

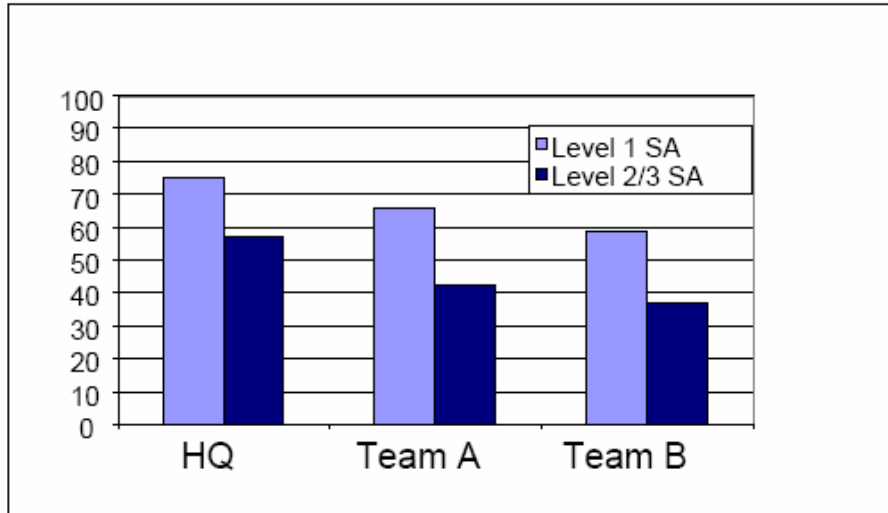- Questionnaires were graded against the answers

Breakdown of CASA questions administered

- Projected location of [blue] unit (map) 2%
- Projected time for [event] to happen 9%
- Erroneous questions 4%
- Current mission / status of [red] unit 2%
- Impact of [blue] mission on [blue] unit 9%
- Others (Lvl 2) 2%
- Location of [blue] unit (map) 36%
- Relationship between [red/civ] unit to [blue] unit 11%
- Location of [red] units (map) 8%
- Current Size Force of [red] unit 4%
- Others (lvl 1) 4%
- Current mision / status of [blue] unit 9%

Legend:
- Level 1 SA
- Level 2 SA
- Level 3 SA
- Decision Making type questions

Results

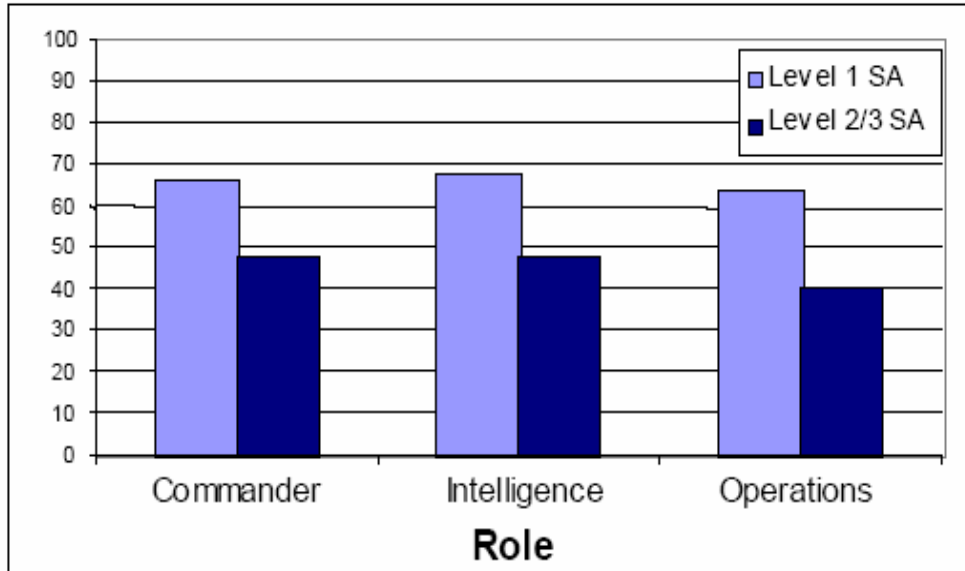SA level of each individual, averaged across 5 assessments

Results

Group SA by Team

Level 1 SA > Level 2/3 SA

- Possible explanation: Level 1 SA information elements are currently better represented or conveyed compared to Levels 2/3 SA information elements.

- Need to enhance Level 2/3 SA representation and conveyance (e.g visualization, symbology, decision support, etc)
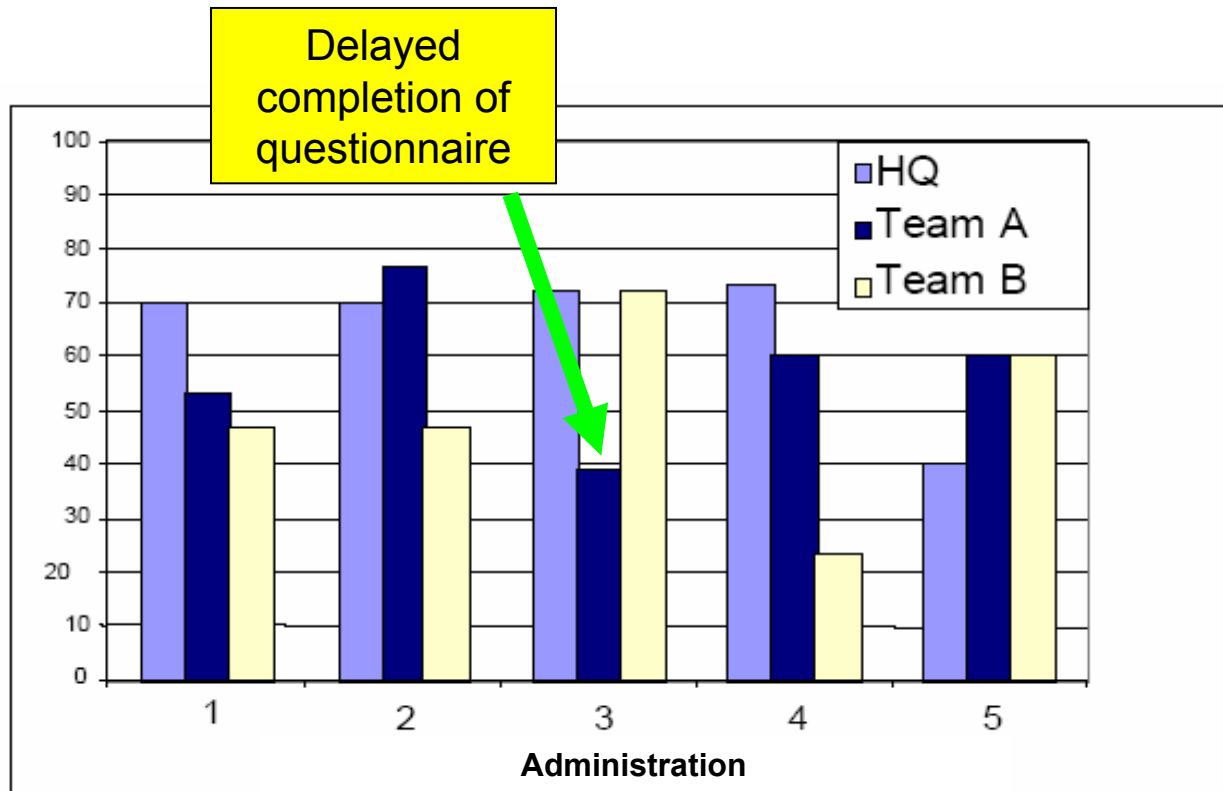
Results

Group SA by Role

- Result consistent with the roles of intelligence and operations officers

- It has been suggested that Commanders' Level 2/3 SA > Level 1 SA as they focus on the big picture. However this is not supported by the results

1. Intelligence SA > Operations SA

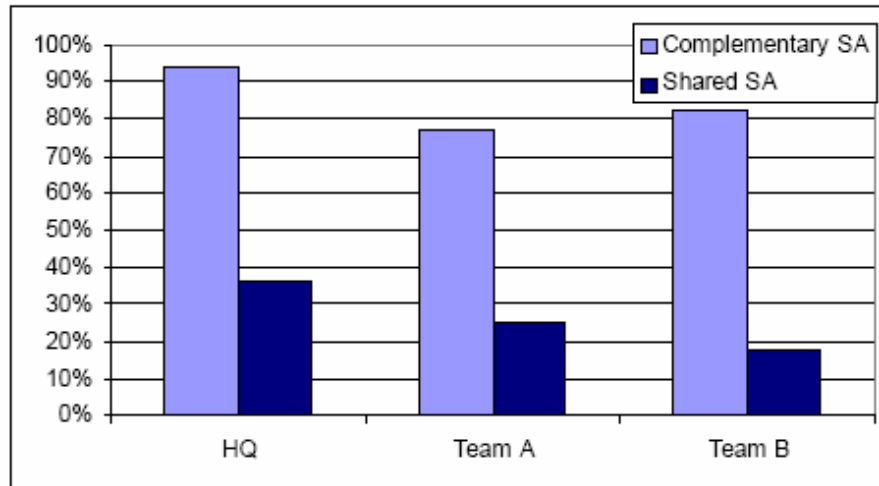2. Level 1 SA > Level 2/3 SA

Results

Group SA by team

SA level of Team A > Team B, except for Administration 3.

Results

- Suggests that information was not shared as freely as may be desirable

- Need to enhance both (co-located) physical communication and (distributed) electronic tools to support communication

**Shared SA** measures how much information each member has in common with others

Complementary SA is a measure of team SA assuming all members readily share information – may be a more appropriate measure in the military C2 context with assigned roles

Issues

- Possible introduction of bias on the part of SMEs
    - With regards to:
        - (i)   Selection of questions
        - (ii) Selection of administration times
    - ➢ Mitigated with multiple SMEs or third-party researchers

- Labour-intensive method
    - Constant monitoring of events
    - Generating and administering questionnaires in a short time frame
    - ➢ Electronic means (e.g. wireless devices) to replace paper administration

- Diagnostic capability – allows experimenters to select or generate SA questions to probe participants on specific issues

Reliability and Validity of CASA

- **Reliability of CASA**
  - Careful phrasing of question templates
  - Generation of actual questions from the question templates
- **Validity of CASA**
  - CASA results (objective measure) were compared with SART results (subjective measure) but they did not correspond
  - Possible Reason – Overestimation of own-self's performance

'Slices' of Objective Measure of SA

Subjective Measure of SA
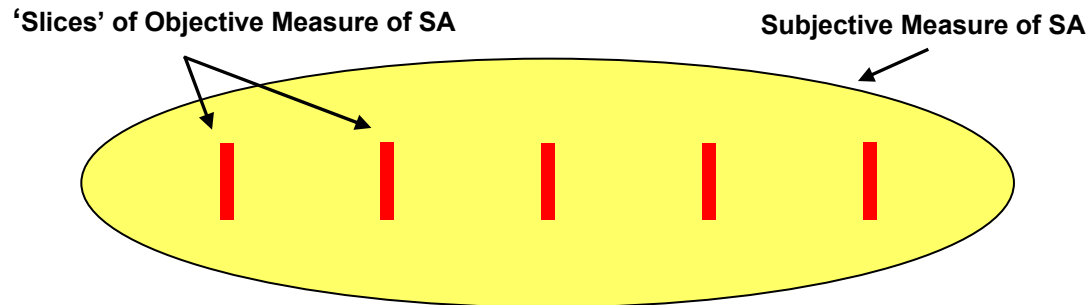
  - Possible Reason – Objective measures of SA measures a slice of an individual's SA over time, whereas subjective measures of SA may be more inclusive base on an individual's overall experience.

Future Work

- Develop new measures of SA comprising both objective and subjective components

- Correlate SA with measures of effectiveness (MOE) e.g. time taken to formulate plans or quality of decisions made

- Correlate SA with workload in command teams

- Further validation of CASA in other experiments and settings

Questions?